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Editorial

Otters as bioindicators of estuarine health: Scientific gaps, field-based insights, and a framework for future research

Alessandra Bez Birolo[1], Marcelo Tosatti[1], Oldemar de Oliveira Carvalho Junior[1], Assiya Haddout[2]

1 *Instituto Ekko Brasil, Florianópolis/SC, Brazil*
2 *Ibn Tofail University, Kenitra, Morocco*
Corresponding author: Assiya Haddout (assiyahd@gmail.com)

Abstract

Estuaries are vital ecosystems bridging terrestrial and marine environments, supporting nutrient cycling, biodiversity, and services like flood protection. Yet, they face threats from pollution, habitat fragmentation, overfishing, and climate change, demanding robust bioindicators for effective monitoring. This synthesis highlights otters—semi-aquatic mustelids such as the Neotropical otter (*Lontra longicaudis*), North American river otter (*Lontra canadensis*), and sea otter (*Enhydra lutris*)—as integrative sentinels, leveraging their reliance on clean water, diverse prey, and connected habitats, plus their meso-predator roles in food webs. Based on 40 years of Projeto Lontra fieldwork in Brazil's Peri Lagoon and global studies, we detail otters' bioindicator value: habitat specificity (e.g., 30% sighting drops in fragmented areas), contaminant sensitivity (bioaccumulation of POPs, metals, microplastics; 66% Toxoplasma positivity), behavioral proxies (spraints showing diet shifts: 70–80% fish), and top-down effects (e.g., suppressing invasive crabs to stabilize marshes, as in 2025 California research). A Scopus bibliometric analysis (1986–2025) exposes biases: 6,300 publications dominated by temperate species (>70% on sea/Eurasian otters), with tropical/estuarine gaps (Neotropical otter: 211 documents, Brazil at 49%). Persistent challenges include sublethal contaminant effects, dispersal, density regulation, and socioeconomic integration. We propose a seven-pillar framework: population scaling, density studies, impact quantification, monitoring harmonization, reintroductions, socioeconomic balancing, and pathogen considerations. This promotes interdisciplinary, equitable collaborations to advance otter-based estuarine management.

Key words: Apex predators, bibliometric analysis, bioindicators, conservation, contaminants, ecosystem health, eDNA, estuarine health, fisheries impacts, habitat management, heavy metals, IUCN, long-term datasets, *Lontra longicaudis*, management, microplastics, monitoring, Neotropical otter, otters, pollution, Scopus, sentinel species, temperate systems, trophic interactions, tropical coastal Brazil

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Introduction

Estuaries are among Earth's most productive ecosystems, functioning as dynamic interfaces where rivers, land, and sea converge to support nutrient cycling, biodiversity, and critical services such as flood buffering and fisheries production (Carvalho Junior 2025; Haddout et al. 2024; Priya et al. 2024).

Yet they face mounting pressures from pollution, habitat loss, overexploitation, and climate change, threats that demand integrative, ecologically grounded monitoring tools (Soeprobowati et al. 2025). While conventional metrics like water chemistry or benthic indices provide valuable snapshots, they often fail to capture cross-scale interactions across hydrological, biological, and anthropogenic domains. Bioindicators that integrate these dimensions are therefore essential for holistic estuarine assessment.

Semi-aquatic mustelids, particularly otters, offer exceptional promise as such integrative sentinels. Species like the Neotropical otter (*Lontra longicaudis*), North American river otter (*Lontra canadensis*), and sea otter (*Enhydra lutris*) occupy meso- to apex-predator roles, depend on clean water and connected habitats, and bioaccumulate contaminants through trophic transfer (de Almeida and Ramos Pereira 2017; Rheingantz et al. 2017). Their presence, behavior, and health reflect the integrity of multiple ecosystem components simultaneously, making them powerful proxies for overall estuarine condition (Carone 2012).

This synthesis draws on 40 years of continuous fieldwork from Projeto Lontra in Brazil's Peri Lagoon, a coastal lagoon system with intermittent marine connectivity, and integrates global literature to evaluate otters' utility as bioindicators in true land–sea transition zones. We emphasize contexts where terrestrial, freshwater, and marine processes intersect, as these settings maximize otters' sensitivity to anthropogenic change and ecological feedbacks (Carvalho Junior 2026; Carvalho-Junior et al. 2021; Carvalho Junior et al. 2023).

Notably, while *L. longicaudis* inhabits diverse freshwater and coastal habitats, its functional integration as a bioindicator is strongest in two specific environments: (i) tidally influenced brackish estuaries and (ii) coastal lagoons with periodic marine exchange. In contrast, purely fluvial systems, lacking tidal influence or saline intrusion, show weaker linkages between otter dynamics and estuarine health metrics. This distinction is critical for defining the scope of otter-based monitoring and is elaborated in Section 2.

Recent studies underscore otters' ecological leverage. In California, recovering sea otter populations suppress invasive crabs, reducing marsh erosion by up to 10 inches per year and enhancing carbon sequestration (Jeppesen et al. 2025). In Brazil, spraint analyses reveal diet shifts that track seasonal hydrology and prey availability, while pathogen screening shows 66% *Toxoplasma gondii* prevalence, even within protected areas, highlighting spillover risks from domestic animals. Despite these advances, tropical estuarine systems remain underrepresented in global research, and operational frameworks for standardized otter-based monitoring are scarce.

This paper addresses these gaps through three aims: (1) synthesize empirical evidence for otters as multi-dimensional bioindicators; (2) quantify global research biases using bibliometric analysis; and (3) propose a scalable, field-tested framework to advance otter-led estuarine management—particularly in data-limited tropical regions.

Otters as bioindicators: Scientific rationale

Otters occupy a distinctive ecological niche that renders them highly responsive and thus informative sentinels of estuarine condition. As semi-aquatic meso-predators, they integrate signals across hydrological, trophic, and

anthropogenic gradients through three interlinked dimensions: habitat dependency, trophic bioaccumulation, and disease ecology. Each dimension offers measurable proxies for ecosystem integrity, as demonstrated by decades of field data from Projeto Lontra and complementary global studies.

Habitat dependency and landscape connectivity

Otters require structurally complex, minimally disturbed habitats that provide shelter, breeding sites, and access to diverse prey. In estuarine contexts, this translates to intact mangroves, riparian buffers, and interconnected lagoon–channel systems. Disruption of these features, through deforestation, shoreline hardening, or aquaculture expansion, rapidly manifests in otter distribution and behavior. In Peri Lagoon, for instance, otter sighting frequency declined by 30% over a decade in areas where Atlantic Forest fragmentation severed terrestrial–aquatic linkages (Carvalho-Junior et al. 2021). Similarly, camera-trap data reveal active avoidance of anthropogenically altered banks, with denning concentrated in zones retaining natural vegetation cover. Fragmentation also restricts dispersal, potentially reducing genetic diversity and increasing inbreeding risks, as documented in recovering southern sea otter populations following historical bottlenecks (Tinker et al. 2016). Such behavioral plasticity underscores otters' sensitivity to landscape-scale change and their utility as early-warning indicators of habitat degradation.

Contaminant bioaccumulation across trophic levels

As high-trophic consumers, otters bioaccumulate persistent pollutants, including heavy metals (e.g., mercury), endocrine-disrupting compounds, polychlorinated biphenyls (PCBs), and microplastics, through dietary intake. Their lipid-rich tissues and fur act as reservoirs, amplifying exposure signals that may remain undetected in water or sediment samples alone. In British Columbia, river otters at industrialized estuaries exhibited mercury concentrations 2–3 times above baseline, despite stable population metrics, highlighting the critical need to assess sublethal physiological effects (O'Hara and Hart 2018). Legacy pollutants such as PCBs continue to pose risks despite regulatory bans, as seen in expert assessments of contaminant impacts on sea otters in San Francisco Bay (Jessup et al. 2007), reinforcing the value of otter tissues for detecting persistent chemical stress. In Brazil, spraint analyses from Peri Lagoon have detected microplastic fibers and synthetic polymers, corroborating findings from Eurasian otter studies in Europe (Luna et al. 2025; Nopp-Mayr et al. 2024). Haematological profiles from captive *Lontra longicaudis* further support this: individuals exposed to urban runoff show elevated leukocyte counts and altered erythrocyte morphology, providing non-lethal biomarkers for wild monitoring (Carvalho-Junior et al. 2025). These data collectively affirm otters' role as integrators of chemical stress across food webs.

Pathogen exposure and spillover dynamics

Beyond abiotic contaminants, otters serve as sentinels of biological health at the wildlife–domestic–human interface. Their proximity to human settlements and dependence on shared waterways expose them to zoonotic pathogens,

particularly in protected areas adjacent to urban or agricultural zones. In Brazil's Taim Ecological Station, a Ramsar site, 66% of sampled *L. longicaudis* tested seropositive for *Toxoplasma gondii*, a protozoan parasite shed exclusively by felids, implicating domestic cat colonies as a primary source (Carvalho-Junior et al. 2025). Similarly, 83% of individuals showed antibodies against canine distemper virus (CDV), suggesting spillover from unvaccinated dogs. These findings reveal a paradox: even legally protected estuaries are not immune to pathogen incursion when landscape permeability permits cross-species contact. Consequently, otter health reflects not only ecological but also socio-ecological conditions, making them uniquely positioned to monitor One Health dynamics in coastal zones.

Behavioral and trophic proxies for ecosystem function

Otters' observable behaviors and diet composition offer non-invasive, cost-effective metrics for tracking estuarine productivity and resilience. Monthly spraint collections in Peri Lagoon document seasonal shifts: fish dominate the diet year-round (70–80%), but crustacean consumption rises to 40% during dry periods, mirroring hydrological constraints on prey availability. Such plasticity signals ecosystem responsiveness rather than instability. Moreover, otters exert top-down regulation that cascades through food webs. In California, recovering sea otter populations suppress invasive green crabs (*Carcinus mænas*), reducing burrowing-induced marsh erosion by up to 25 cm yr^{-1}, stabilizing marsh edges, and enhancing carbon sequestration (Jeppesen et al. 2025; Hughes et al. 2019). While direct evidence of analogous effects in Neotropical systems remains limited, preliminary data suggest *L. longicaudis* predation helps maintain invertebrate diversity in brackish channels, supporting the hypothesis that otters contribute to functional stability across biogeographic realms, albeit through context-dependent mechanisms.

Global research landscape on otters

Over the past four decades, otter research has expanded substantially, reflecting growing global concern for freshwater and coastal ecosystem health, biodiversity conservation, and apex predator ecology. A Scopus-based bibliometric analysis covering the period 1986–2025 indicates that a general search for "otter*" retrieves approximately 6,300 documents, with a marked acceleration in publication output since around 2015 (Fig. 1). This growth has been driven primarily by studies on general ecology, population dynamics, and conservation biology, while more applied themes, such as bioindicator frameworks, estuarine integration, and data-driven monitoring, have developed more slowly.

Although recent years have seen increasing attention to pollution, monitoring, and estuarine or coastal systems, the systematic use of otters as quantitative bioindicators remains comparatively limited. Similarly, emerging tools such as environmental DNA (eDNA), artificial intelligence–assisted image analysis, and integrated monitoring platforms are still under-represented in the otter literature. While AI-assisted image analysis enhances detection rates across 15,000+ camera-trap images, individual identification in *Lontra longicaudis* remains challenging due to its uniform pelage. As such, we rely primarily on VHF/

GPS telemetry and den fidelity for individual tracking, with camera traps serving as complementary tools for presence/absence confirmation and behavioral validation, not as primary identifiers.

These patterns suggest that otters are widely recognised as ecologically important species, yet their full potential as sentinels of aquatic ecosystem health has not been consistently operationalised across regions and methodological approaches. Fig. 2 provides a focused view of how this evolution has unfolded within Brazil, visualising not only the growth in volume but also the thematic priorities and gaps that define the country's scientific output over four decades.

Country-filtered Scopus searches indicate approximately 276 otter-related publications from Brazil, with steady growth since the early 2000s. However,

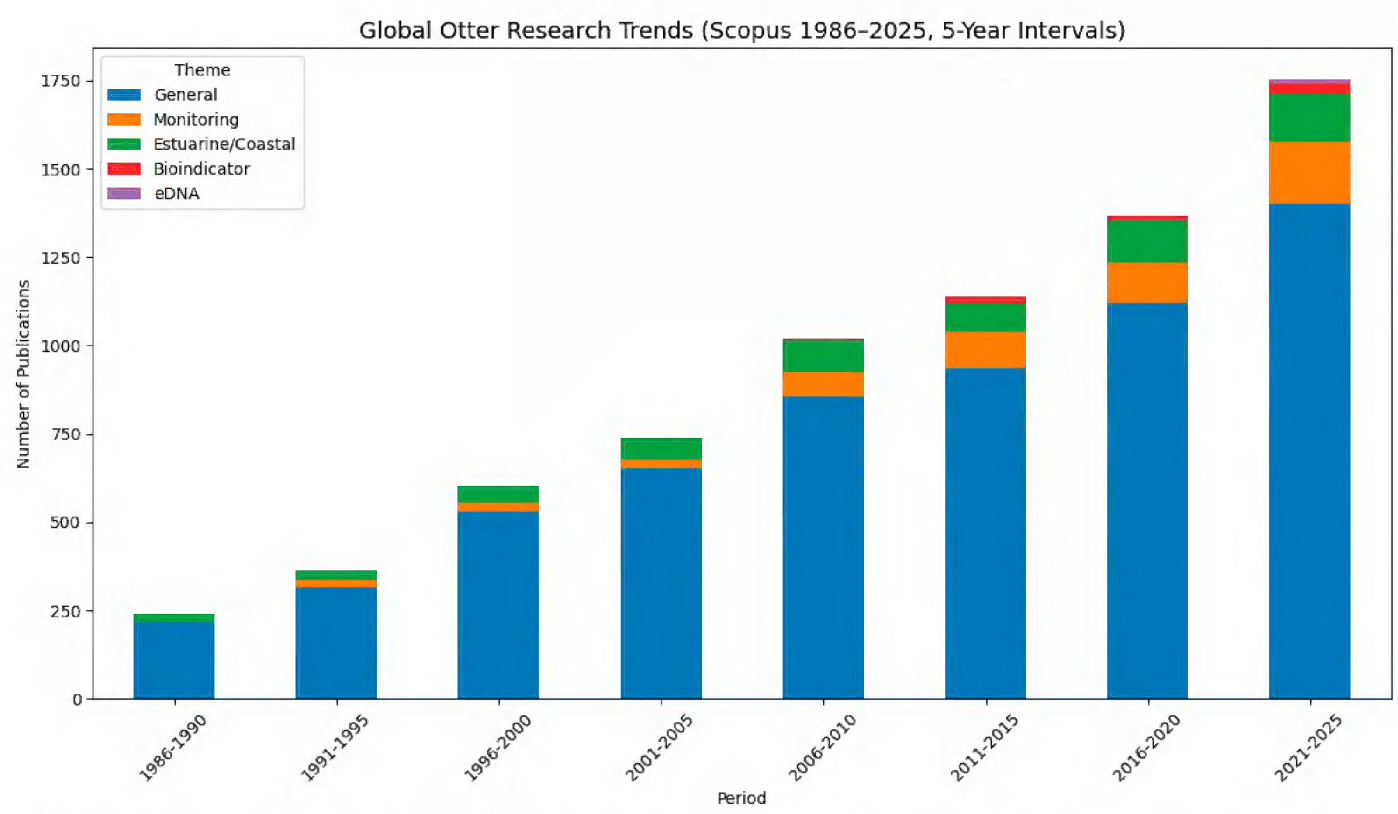

Figure 1. Global otter research trends (Scopus 1986–2025, 5-year intervals). Stacked bar chart illustrating the dominance of general otter studies (blue) and the smaller but growing contributions from monitoring (orange), estuarine/coastal (green), bioindicator (red), and eDNA (purple) themes.

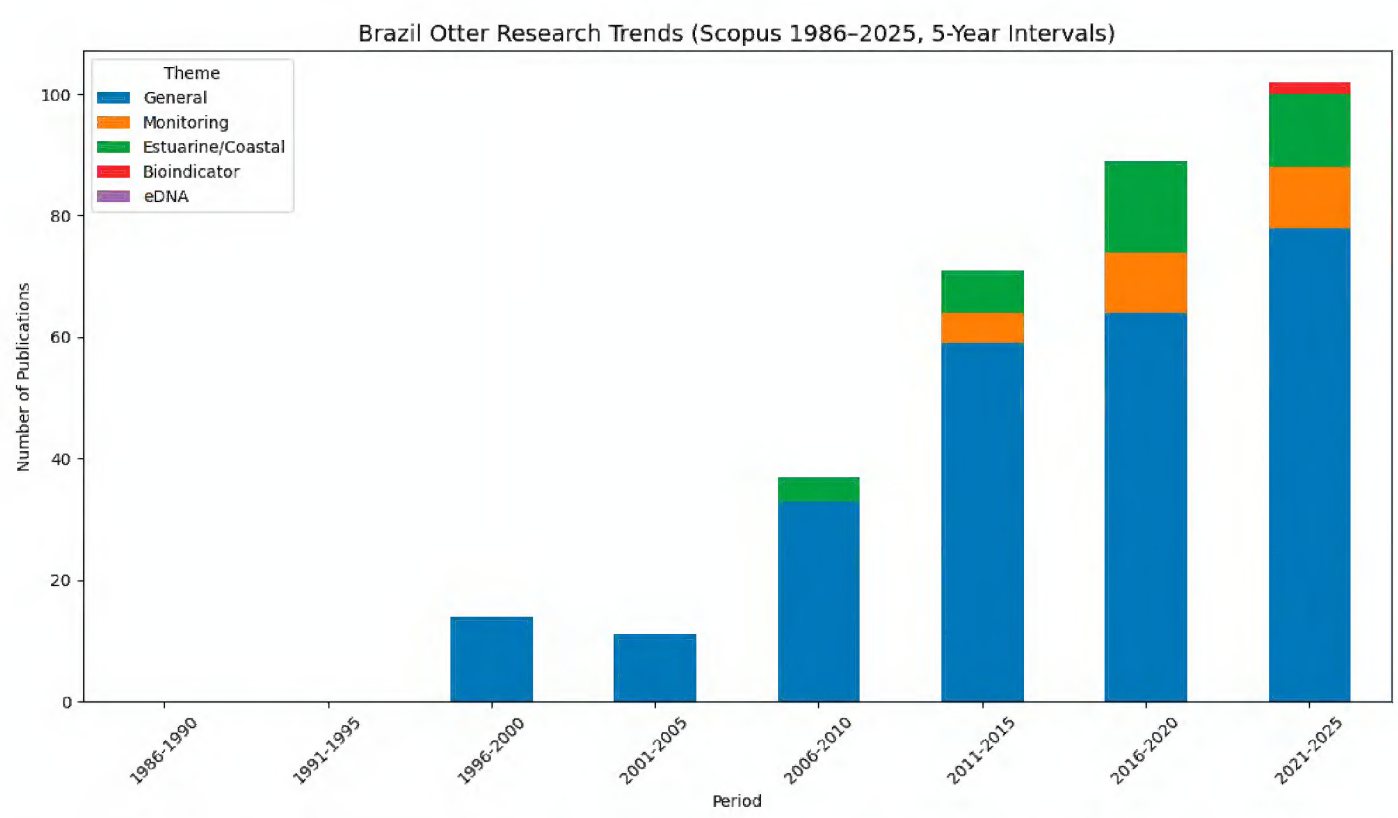

Figure 2. Brazil otter research trends (Scopus 1986–2025, 5-year intervals). Stacked bar chart showing consistent growth in general publications (blue) but minimal development in monitoring, estuarine, bioindicator, and eDNA research.

most Brazilian studies remain focused on descriptive ecology and conservation status, with comparatively few contributions addressing estuarine systems, standardised bioindicator frameworks, or open and reusable data infrastructures; despite Brazil's extensive coastline, large estuarine complexes, and high societal dependence on aquatic ecosystem services.

To visualise the intellectual architecture of global otter research, we mapped keyword co-occurrence across 6,300 publications (1986–2025) using VOSviewer software (van Eck and Waltman 2010). The resulting network reveals three dominant thematic clusters: (1) taxonomy and species ecology, largely centred on the Eurasian otter (*Lutra lutra*) and sea otter (*Enhydra lutris*); (2) pollution and trophic interactions, including heavy metals, microplastics, and fisheries-related impacts; and (3) conservation and habitat management, predominantly within temperate freshwater systems. In contrast, tropical estuarine contexts, long-term monitoring programmes, and explicit bioindicator applications appear at the periphery of the network.

Fig. 3 visually reinforces this imbalance. While core research clusters are densely interconnected around temperate species and general ecological themes, terms directly associated with otters as bioindicators, such as "bioindicator," "estuarine health," "sentinel species," "tropical monitoring," and "long-term dataset", form sparse, isolated nodes on the network's periphery. This spatial marginalization underscores a critical gap. Despite growing recognition of otters' integrative potential, their formal application within operational bioindicator frameworks, especially in tropical estuaries, remains underdeveloped and disconnected from mainstream research trajectories.

This structural inequality in global otter research is further illuminated by country co-authorship networks (Fig. 4), which map the collaborative architecture underpinning scientific output. The visualization reveals dense, highly interconnected clusters centered on the United States, Canada, the United Kingdom, and continental Europe, regions where institutional capacity, funding, and

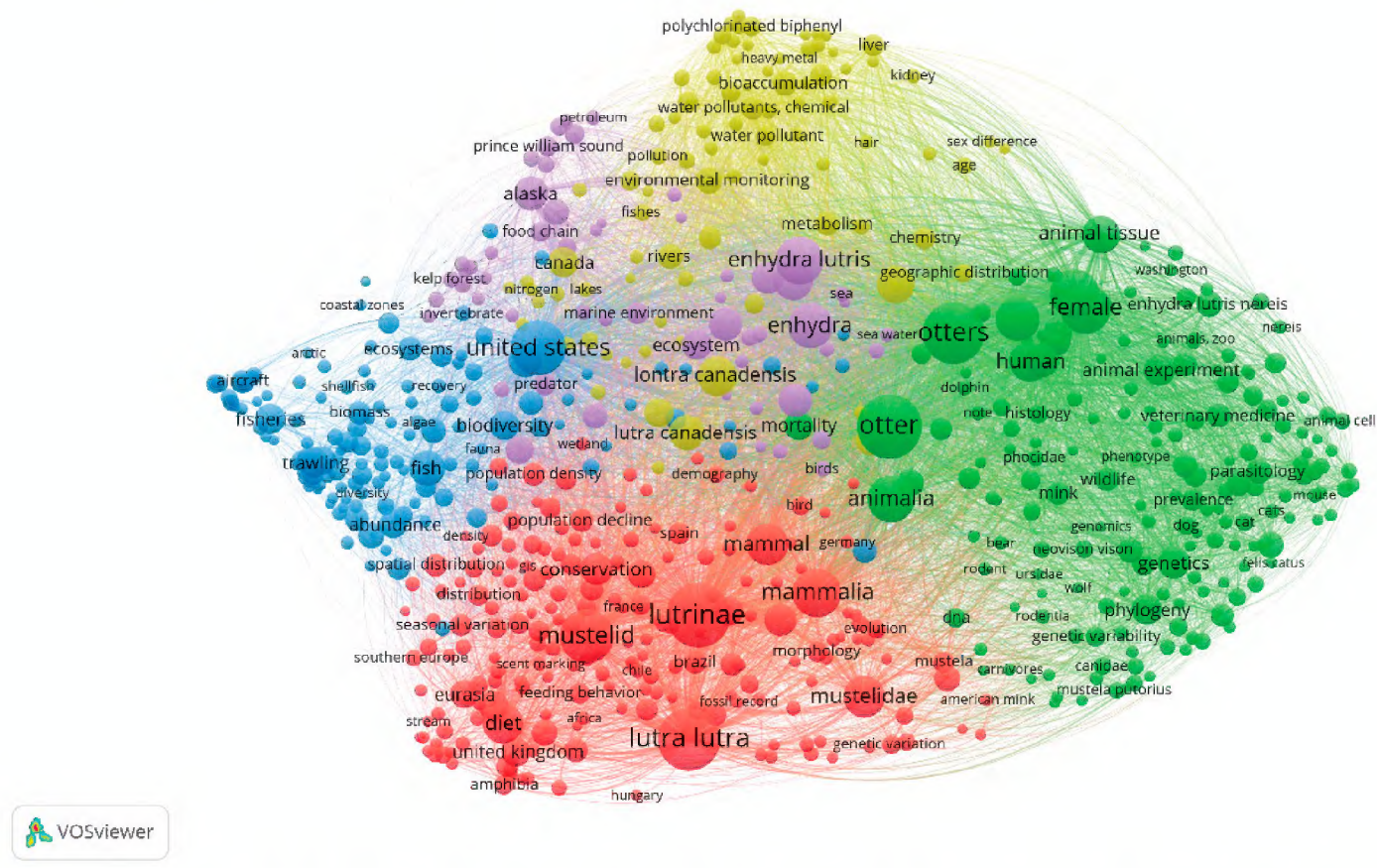

Figure 3. VOSviewer keyword co-occurrence network for otter research (Scopus 1986–2025). Colours indicate research clusters; Eurasian and sea otter studies dominate, while tropical and bioindicator themes are marginal.

publishing infrastructure converge to sustain high-volume, multi-institutional research programs. In contrast, Brazil appears as a distinct, less-connected node within a broader Global South group, with fewer cross-border collaborations and weaker ties to the dominant Northern networks. This spatial segregation in authorship patterns underscores how knowledge production remains concentrated in a few geographic hubs, while tropical regions, even those generating foundational long-term datasets like Projeto Lontra, struggle to integrate into the global scholarly conversation. The relative isolation of Brazil's research community, despite its leading role in *Lontra longicaudis* studies, exemplifies the systemic barriers that limit the visibility and impact of Southern science.

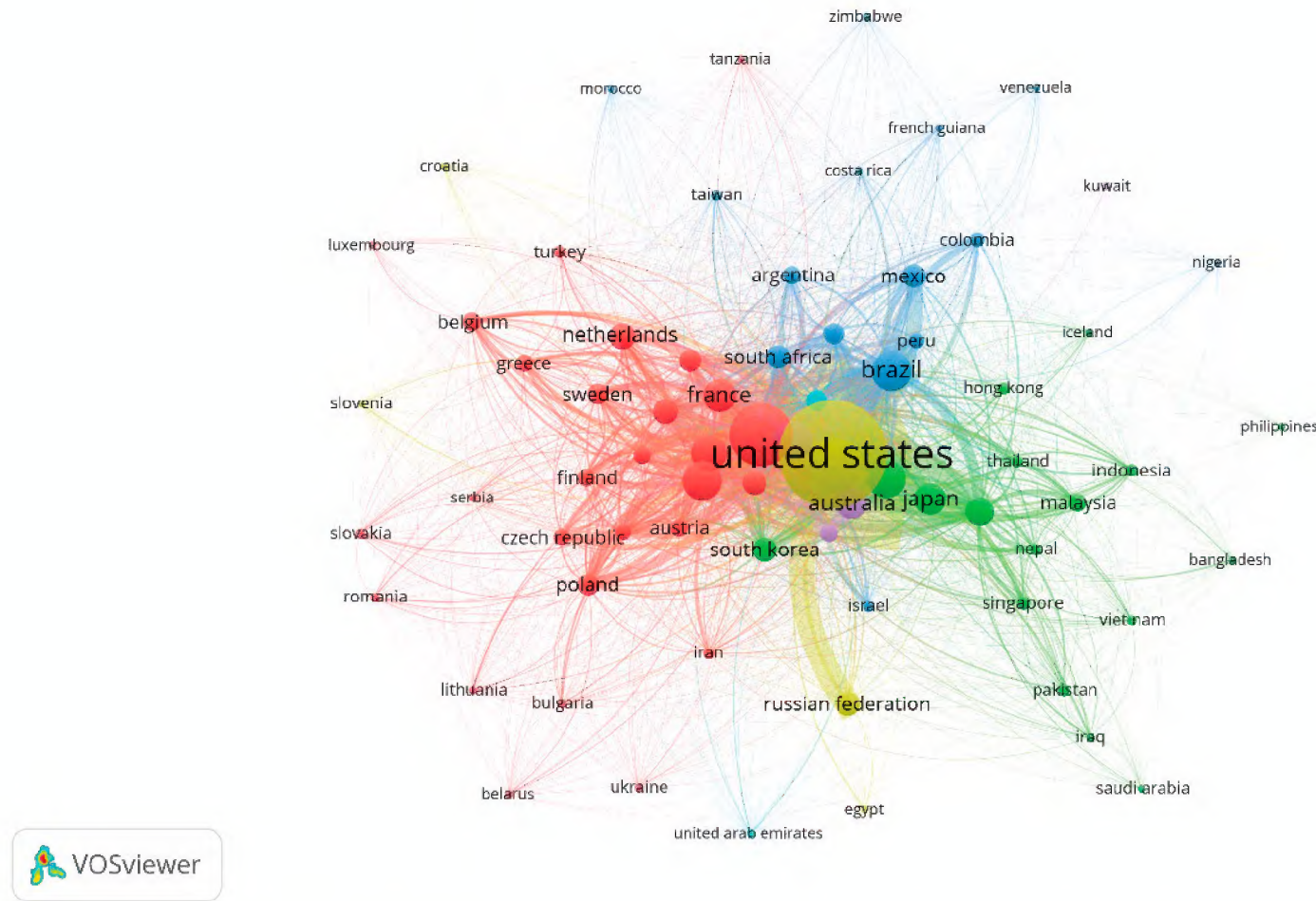

Figure 4. VOSviewer country co-occurrence network for otter research (Scopus 1986–2025). Node size reflects publication volume; colours indicate collaboration clusters. Brazil is visible but positioned in a less connected Global South group.

These imbalances become most apparent when research output is examined at the species level. A species-specific bibliometric assessment covering all 13 extant otter species reveals that three temperate species, the sea otter (*Enhydra lutris*, 1,157 documents), Eurasian otter (*Lutra lutra*, 1,123 documents), and North American river otter (*Lontra canadensis*, 445 documents), together account for more than 70% of all otter-related publications (Table 1). In contrast, tropical species are markedly under-represented. The Neotropical otter (*Lontra longicaudis*), despite its wide distribution across Central and South America and its strong ecological association with estuarine, lagoon, and coastal habitats, is represented by only 211 documents (<4% of global output). Notably, Brazil contributes nearly half of these publications (~49%, 104 documents) (Fig. 5), positioning the country as the principal global knowledge hub for this species.

Within this national contribution, a species-specific Scopus search shows that Instituto Ekko Brasil is associated with only four indexed articles

Table 1. Global publication output by otter species (Scopus 1986–2025).

Rank		Common Name	Scientific Name	Main Geographic Range	Primary Habitat Focus	Leading Country (Approx. Contribution)***	Scopus Documents**	IUCN Conservation Status*
1		Sea otter	*Enhydra lutris*	North Pacific	Marine/coastal	United States (~75%)	1,157	Endangered
2		Eurasian otter	*Lutra lutra*	Europe, Asia, North Africa	Riverine, lakes, coastal	United Kingdom (~21%), Spain (~14%)	1,123	Near Threatened
3		North American river otter	*Lontra canadensis*	North America	Riverine, lakes, wetlands	United States (~69%), Canada (~22%)	445	Least Concern
4		**Neotropical otter**	***Lontra longicaudis***	**Central & South America (south of Mexico)**	**Riverine, estuarine, coastal, lagoons**	**Brazil (~49%)⁺**	**211**	**Near Threatened**
5		Giant otter	*Pteronura brasiliensis*	Amazon basin, Pantanal	**Riverine/ floodplain (fluvial)**	Brazil (~48%)⁺	171	Endangered
6		Asian small-clawed otter	*Aonyx cinereus*	Southeast Asia	Riverine, wetlands, rice fields	United States (~24%), India (~17%)	152	Vulnerable
7		Smooth-coated otter	*Lutrogale perspicillata*	South & Southeast Asia	Riverine, wetlands	India (~45%)	150	Vulnerable
8		Marine otter	*Lontra felina*	Pacific coast South America	Marine/coastal	Chile (~47%)	74	Endangered
9		African clawless otter	*Aonyx capensis*	Sub-Saharan Africa	Riverine, wetlands	South Africa (~71%)	73	Near Threatened
10		Southern river otter	*Lontra provocax*	Chile, Argentina	Riverine, lakes	Chile (~53%)	46	Endangered
11		Spotted-necked otter	*Hydrictis maculicollis*	Sub-Saharan Africa	Riverine, lakes	South Africa (~51%)	37	Near Threatened
12		Hairy-nosed otter	*Lutra sumatrana*	Southeast Asia	Riverine, wetlands	Malaysia (~31%)	32	Endangered
13		Congo clawless otter	*Aonyx congicus*	Central Africa	Riverine, wetlands, terrestrial foraging	United States (~60%)	5	Near Threatened

*Conservation status follows the IUCN Red List / IUCN SSC Otter Specialist Group global assessments (latest available, accessed 2024–2025).
**Document counts are based on species-specific Scopus TITLE-ABS-KEY searches including accepted synonyms (1986–2025).
***Leading country reflects the highest share of author affiliations in Scopus and indicates research concentration, not species endemism.
⁺Although *Pteronura brasiliensis* (giant otter) is a flagship South American species, the majority of its published research focuses on fluvial (riverine and floodplain) systems, particularly in the Amazon basin and Pantanal wetlands. In contrast, *Lontra longicaudis* is more frequently associated with estuarine, coastal, and lagoon environments, reinforcing its central relevance to estuarine bioindicator frameworks and the thematic focus of this Topical Collection.

(Carvalho-Junior et al. 2013, 2021, 2025; Barbosa et al. 2021). This figure vastly underrepresents four decades of continuous fieldwork, educational outreach, and methodological innovation, much of which exists as grey literature (e.g., IUCN Otter Specialist Group Bulletins, technical reports, institutional archives) or predates Scopus indexing of key regional journals.

This persistent underrepresentation reflects a systemic gap in global conservation science. Tropical estuarine systems, where land, freshwater, and marine pro-

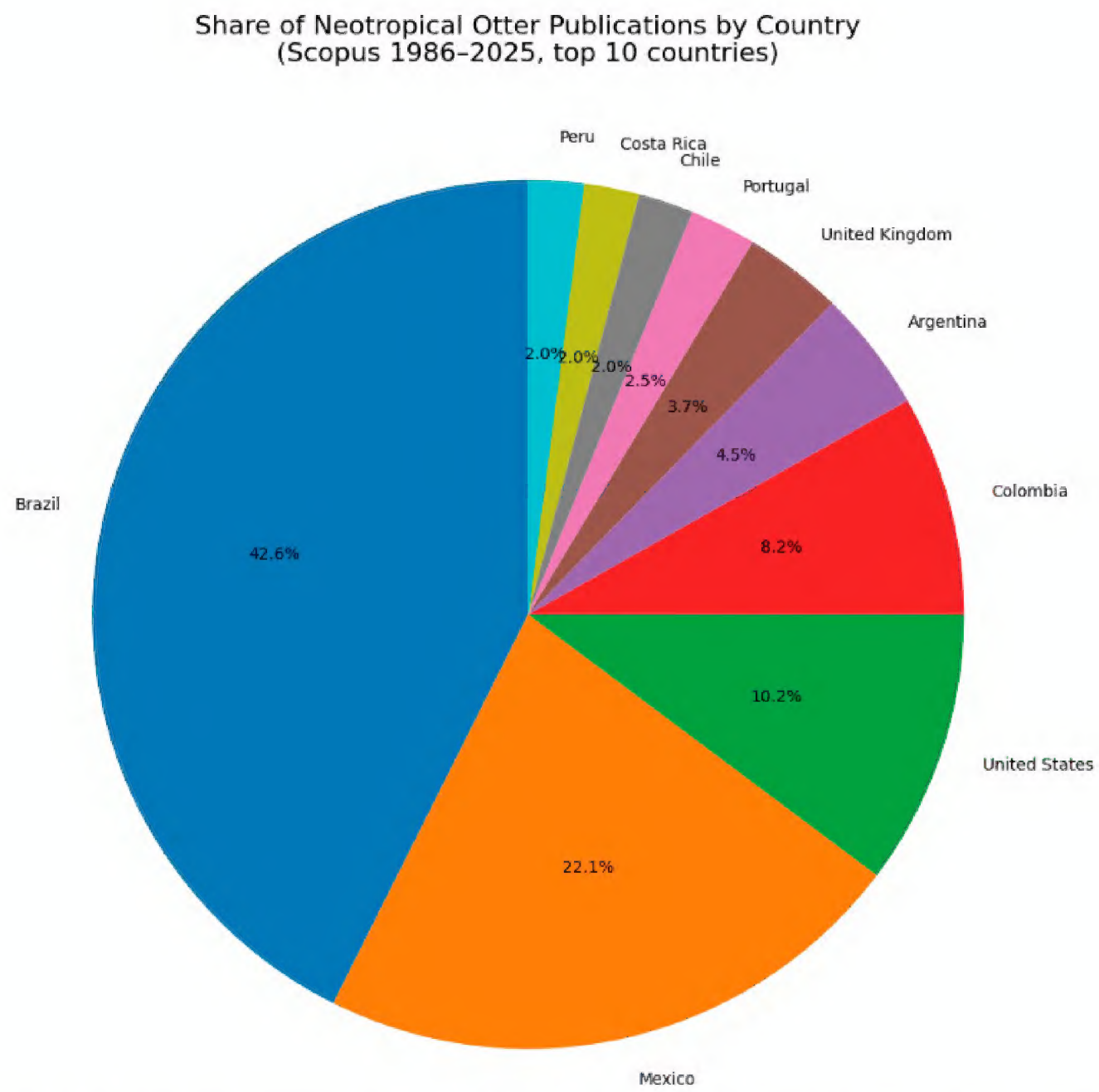

Figure 5. Share of publications on the Neotropical otter (*Lontra longicaudis*) by country (Scopus 1986–2025, top 10 countries). Pie chart demonstrating Brazil's dominant contribution (~49% of global output).

cesses converge, are among the most threatened yet least monitored ecosystems worldwide. Long-term datasets like Projeto Lontra's 40-year record provide irreplaceable insights into otter responses to hydrological change, contaminant flux, and pathogen spillover, yet much of this work remains invisible in major databases (Carvalho Junior 2026). Database coverage thus reflects publication visibility, not scientific validity. The exclusion of non-English, non-indexed, and community-led knowledge systematically undervalues the depth of field-based understanding available for species like *L. longicaudis*, particularly in the Global South.

Most existing studies focus on riverine environments, while land–sea interface systems remain under-explored. This absence is particularly evident when compared with recent European studies that have successfully applied non-invasive scat analyses to assess microplastic contamination, heavy metals, and synthetic debris using otters as sentinels (e.g., Nopp-Mayr et al. 2024; Luna et al. 2025). Foundational work has long established otters as effective long-term biomonitors due to their high trophic position, broad home ranges, and integration of aquatic food webs (Kruuk 2006). However, comparable, methodologically integrated bioindicator frameworks remain rare in tropical estuarine environments.

To operationalise otter-based monitoring, the *Projeto Lontra* is finalising the Otter Health Index (OHI), a low-cost, standardised toolkit combining scat frequency, toxicology, community perception, and habitat connectivity metrics, designed for adoption by municipalities and NGOs across the Global South. By mobilising Pro-

jeto Lontra's 40-year longitudinal dataset on *Lontra longicaudis*, the longest continuous record available for any tropical otter and integrating innovative monitoring approaches, citizen science, and open-access protocols, this synthesis repositions tropical estuarine otters at the centre of international bioindicator research.

An operational framework for otter-based estuarine monitoring

To translate the bioindicator potential of otters into actionable conservation practice, we propose a structured, seven-pillar framework grounded in four decades of Projeto Lontra field experience and aligned with global monitoring needs. This framework is designed to be adaptable across estuarine contexts, with particular relevance for tropical systems where resources and infrastructure may be limited.

1. Population Scaling and Density Estimation. Standardized protocols for estimating otter abundance, using spraint frequency, VHF/GPS telemetry, and den fidelity, are essential for detecting trends. Camera traps serve as complementary tools for presence/absence validation but are insufficient for individual identification in uniformly pelaged species like *L. longicaudis*.
2. Density–Health Linkage. Correlate population metrics with physiological indicators, including haematological and biochemical profiles (e.g., leukocyte elevation in exposed individuals), and contaminant loads in spraints or tissues (e.g., heavy metals, microplastics, POPs).
3. Impact Quantification. Measure otter-mediated effects on prey communities and habitat structure. For example, predation on burrowing crustaceans can stabilize marsh banks and enhance seagrass resilience, a trophic cascade observed in both temperate and emerging tropical datasets.
4. Monitoring Harmonization. Adopt unified, low-cost methods for spraint collection, diet analysis, and habitat assessment to enable cross-site comparison and meta-analyses. Protocols should be open-access and co-developed with local stakeholders.
5. Reintroduction and Translocation Criteria. Define site suitability based on connectivity, contaminant thresholds, pathogen risk (e.g., canine distemper virus seroprevalence), and community acceptance, drawing lessons from tribal-led sea otter reintroductions in the U.S. Pacific Northwest.
6. Socioeconomic Integration. Embed monitoring within community-based conservation, leveraging citizen science and local ecological knowledge. In Brazil, partnerships with municipalities and NGOs have enhanced data continuity and reduced human–otter conflict.
7. Pathogen and Zoonotic Surveillance. Implement routine screening for *Toxoplasma gondii*, CDV, and other zoonoses, recognizing otters as sentinels of landscape-level health at the wildlife–domestic–human interface.

These pillars inform the Otter Health Index (OHI), a practical toolkit currently being finalized by Instituto Ekko Brasil. The OHI combines four core metrics: (a) Spraint frequency (proxy for relative abundance); (b) Toxicological burden (from non-invasive scat sampling); (c) Habitat connectivity (GIS-based corridor analysis); and (d) Community perception (via structured interviews).

Designed for adoption by environmental agencies, NGOs, and municipal governments in the Global South, the OHI requires minimal equipment and

leverages existing field capacities. By standardizing data collection while accommodating local context, it bridges the gap between long-term science and on-the-ground management.

This framework does not assume universal applicability; rather, it offers a modular foundation that can be calibrated to regional priorities, species ecology, and institutional capacity. Its ultimate goal is to position otters not merely as subjects of study, but as active agents in diagnosing and safeguarding estuarine health.

Conclusion

Otters stand as emblematic sentinels of estuarine health, integrating ecological, behavioral, and physiological responses to environmental stressors across spatial and temporal scales. This synthesis, grounded in nearly four decades of Projeto Lontra fieldwork and a comprehensive bibliometric analysis of global otter research (1986–2025), confirms their value as multidimensional bioindicators while exposing persistent biases toward temperate species and systems. Despite robust evidence from Brazil, California, and Europe on otters' roles in habitat maintenance, contaminant bioaccumulation, diet-based ecosystem tracking, and pathogen surveillance, tropical estuarine contexts remain critically underrepresented in both literature and monitoring practice.

To translate this knowledge into tangible conservation outcomes, we offer the following actionable recommendations for environmental agencies, municipal managers, NGOs, and research institutions:

1. Prioritize long-term otter monitoring in tropical land–sea transition zones, particularly in tidally influenced estuaries and coastal lagoons where hydrological connectivity maximizes bioindicator sensitivity. Even basic protocols, such as monthly spraint surveys along standardized transects, can generate high-value data on prey dynamics, contaminant exposure, and habitat use.
2. Integrate non-invasive biomarkers into routine assessments, including toxicological screening of scats for microplastics, heavy metals, and endocrine disruptors, alongside haematological baselines from rehabilitation centers or captive individuals. These metrics reveal sublethal impacts invisible to population counts alone.
3. Adopt the Otter Health Index (OHI), a low-cost, modular toolkit currently being finalized by Instituto Ekko Brasil, which combines four core indicators: (i) relative abundance (via spraint frequency), (ii) contaminant burden, (iii) habitat connectivity (GIS-based corridor mapping), and (iv) community perception (structured interviews). Designed for resource-limited settings, the OHI enables standardized reporting without requiring advanced laboratory infrastructure.
4. Strengthen One Health surveillance at the wildlife–domestic–human interface by routinely testing otters for zoonotic pathogens such as *Toxoplasma gondii* and canine distemper virus (CDV). Positive detections should trigger coordinated actions with public health and veterinary services to manage domestic animal populations near protected estuaries.

5. Bridge the visibility gap for Global South science by co-publishing findings in open-access platforms, contributing grey literature to international repositories (e.g., IUCN Otter Specialist Group Bulletin), and partnering with northern institutions through equitable South–North collaborations that recognize long-term datasets as scientific infrastructure.

By implementing these steps, practitioners can move beyond symbolic conservation toward operational, evidence-based stewardship of estuarine ecosystems. The Neotropical otter (*Lontra longicaudis*), supported by frameworks like the seven-pillar model and tools like the OHI, is not only a beneficiary of protection but an active diagnostic agent in the pursuit of resilient, healthy coastlines. Safeguarding otters, therefore, means safeguarding the intricate web of processes that sustain estuaries themselves and the human communities that depend on them.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

Use of AI

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Author contributions

All authors have contributed equally.

Author ORCIDs

Alessandra Bez Birolo https://orcid.org/0000-0001-7380-119X
Marcelo Tosatti https://orcid.org/0009-0002-4838-0375
Oldemar de Oliveira Carvalho Junior https://orcid.org/0000-0001-7776-0022
Assiya Haddout https://orcid.org/0000-0001-7214-4044

Data availability

All of the data that support the findings of this study are available in the main text.

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